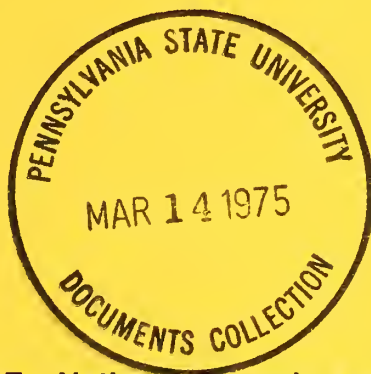


Federal Plan for Environmental Data Buoys

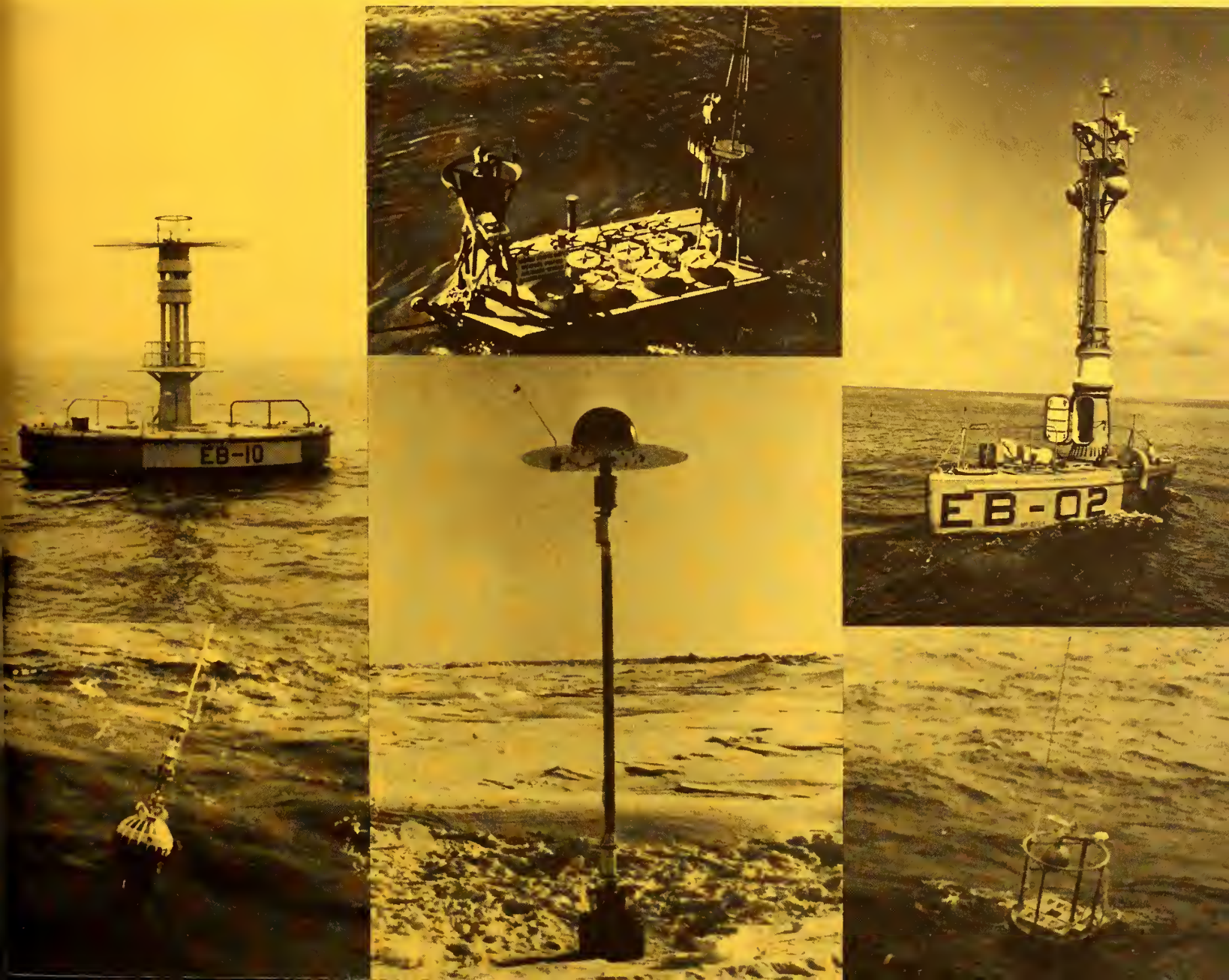
FEDERAL COORDINATOR FOR
MARINE ENVIRONMENTAL
PREDICTION



FISCAL YEAR 1975



U. S. DEPARTMENT OF COMMERCE • National Oceanic and Atmospheric Administration



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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
FEDERAL COORDINATOR FOR MARINE
ENVIRONMENTAL PREDICTION

FEDERAL PLAN
FOR
ENVIRONMENTAL DATA BUOYS

Rockville, Md.
November 1974

FOREWORD

This Plan places environmental data buoys in perspective as essential elements complementary to ships, aircraft and satellites in a marine environmental monitoring system which supports warnings, assessment and prediction services, and oceanic research. These activities serve oceanic areas and coastal communities in the interests of safety of life and property, efficiency of operation, economic development, and energy transportation and exploration with due regard for environmental preservation and enhancement.

This Plan does not include certain classified military requirements for environmental data buoys. These needs are being addressed in a supplemental plan to be prepared by the Department of Defense.

The importance of environmental data buoys in marine monitoring has been specifically recognized in a series of national reports dating to the 1959 National Academy of Sciences' Committee on Oceanography (NASCO) report: Oceanography 1960 to 1970. A second NASCO report, Oceanography 1966, recommended environmental data collection by automatic telemetering buoys and called for development efforts. The Ocean Engineering Panel of the Interagency Committee on Oceanography in 1966 and its successor Committee on Marine Research, Education, and Facilities in 1967 recommended a National Data Buoy Development Project within the Department of Transportation, and this recommendation was implemented.

The President's Commission on Marine Sciences, Engineering, and Resources in its Report Our Nation and the Sea called for the development of a pilot buoy network as one of six national projects. With the implementation of the President's Reorganization Plan No. 4, the National Data Buoy Development Project was transferred to NOAA and subsequently designated to be a focus for not only national buoy technological development but also data buoy applications in operations and research as part of a basic marine observations program.

Three major planning activities related to Federal data buoy systems are discussed: support of monitoring, forecast, and warning services; support of scientific research; and development of buoy technology. The fiscal data presented are FY 74 spending and those amounts requested by the President for FY 75. Post-1975 activity is mentioned for planning purposes only--and does not represent a commitment in scheduling or funding.

This Plan was prepared by the Interagency Committee for Marine Environmental Prediction (ICMAREP). Agencies represented on this Committee include the Departments of Commerce, Defense, the Interior, and Transportation; the Environmental Protection Agency; National Aeronautics and Space Administration; the National Science Foundation; and the Smithsonian Institution.

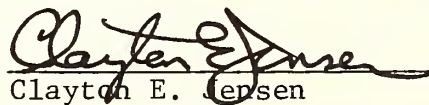

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EXECUTIVE SUMMARY

Man's increasing dependence on the ocean for energy, minerals, food, transportation and recreation, requires new and improved forecast and warning services if this potential is to be realized with due concern for safety and maintaining marine environmental quality. The effectiveness of environmental service programs to meet this challenge is being limited by the lack of adequate oceanic observations.

The present oceanic monitoring system is a mix of many elements involving satellites, cooperative ships, aircraft and buoys. Satellites make possible the routine global monitoring of the atmosphere down to the sea surface. Satellite-borne sensors provide cloud imagery, vertical temperature soundings of the atmosphere and in cloud-free areas, sea surface temperatures, sea ice distribution and certain gross features of the sea surface conditions. Cooperative ships obtain surface meteorological observations, sea surface temperatures and sea-state conditions. These observations are available on an irregular basis as they are taken only while the vessels are at sea. Moreover, the area coverage is restricted since the data are acquired only over established shipping lanes. Severe weather conditions which are of great importance in ocean forecast and monitoring are usually avoided by ships. Aircraft provide high resolution information of sea surface temperature and some additional features of ocean conditions over areas that are limited by aircraft range. Buoys are supplying surface meteorological observations and limited surface and subsurface oceanographic data under all weather conditions.

There is a need to fill certain existing gaps in oceanic monitoring. Routine surface and subsurface observations from key areas in the ocean are essential for providing the time-series measurements that are basic to warnings, forecasts, climate studies and research. The environmental data buoy represents a ready technological opportunity to enhance ocean monitoring capability and make available additional information to support the rational development of the ocean and its resources.

This plan represents a phased schedule for the deployment of 36 environmental data buoys. These include the purchase of new buoys and the retro-fitting of 6 existing deep ocean buoys with improved payload systems currently in inventory. Based on national needs, buoys are to be positioned in the following priority areas: the Gulf of Alaska, off the east and west coasts of the United States, the Gulf of Mexico, and the Great Lakes. For the first phase, six new prototype buoys will be emplaced in the Gulf of Alaska and northeast Pacific Ocean for operational use. The succeeding phases of the plan will be implemented as funding will permit. Included also are details of the technological development effort that will be pursued to achieve optimum capability and reliability of buoy systems and components.

Three areas of buoy application are discussed. They are:

- Buoys for basic monitoring to support forecasting, warning, and assessment services.

- Buoys for specialized monitoring to support climate studies and other scientific research.
- Buoy technology development.

BUOYS FOR BASIC MONITORING

The functions of monitoring, predicting, warning, and assessing are all interrelated. Monitoring, however, underpins all other functions for without data, the prediction, warning, and assessment of environmental conditions would not be possible. Key areas with representative locations (see accompanying figure) for buoy deployment have been identified to support improved warning, forecast, and assessment services in four critical areas; the Gulf of Alaska and northeast Pacific Ocean; the east coast of the United States, the Gulf of Mexico, and the Great Lakes.

Shortages of oil and other essential resources have focused increased activity in the oceanic environment. As a result, first priority in the deployment of buoys is being accorded to the Gulf of Alaska and northeast Pacific where additional monitoring is vitally needed to support the many activities there including the transportation of energy resources over the marine leg of the Trans-Alaska Pipeline System. Information supplied by these buoys will also provide the first opportunity to delineate the magnitude and intensity of eastward moving Pacific weather systems and result in more timely dissemination of warnings and forecasts of hazardous oceanic phenomenon affecting this area. The data will also permit more detailed forecasts of environmental conditions at port terminals to minimize the possibility of catastrophic oil and other hazardous spills resulting from grounding or collision, and to support other shipping and recreational activities. In addition buoy systems will ultimately be used for assessing long-term trends in environmental quality.

The east coast of the United States is constantly exposed to destructive oceanic storms and related oceanographic phenomena. Positioning of buoys in strategic locations off the east coast will provide oceanographic and meteorological data that can be used in detailed forecast models to provide more accurate short-range (0-6 hours) forecasts of the intensity and landfall of hurricanes and other storms as well as early warnings of storm surge and other destructive oceanic conditions. In addition these data will also be used to improve the accuracy of longer range (12-36 hours) forecasts. Undetected winter storms which in the past have paralyzed major cities in the northeast with heavy snowfalls can now be observed in their incipient stages over the ocean and warnings issued for appropriate and timely community response.

The Gulf of Mexico represents an important area for the production of energy and food. In addition to its vulnerability to hurricanes from the Caribbean, it can also generate storms of destructive proportion that not only threaten waterborne activities, but also substantial portions of the southern U.S. and adjacent offshore areas. The deployment of buoys in the Gulf will provide the environmental information needed to upgrade oceanic warning and forecast services and permit the eventual monitoring of environmental quality

trends so that the delicate balance between energy production, fisheries and recreational activities can be sustained without mutual detriment.

The use of buoys in the Great Lakes will provide specific characteristics on lake storms and thereby improve the forecast and warning services to shipping, lakeshore, and marine recreational interests. Moreover these data will identify environmental factors needed by management for hydropower, public water supply, waste disposal and fish productivity.

The number of buoys and the deployment configuration shown in the accompanying figure is formulated for planning purposes, on the following principal considerations:

- The guiding requirement is for data to support weather forecasting as described above.
- Synoptic meteorological systems typically have scales of the order of 2000 km and move at 30 kph. Hurricanes are smaller. Thus, buoy spacings of the order of 500 km, 300-1000 km from shore would monitor these systems and provide 12-36 hour warnings.
- Storm tracks and development areas require a concentration in the Gulf of Alaska, the Atlantic Seaboard, the Great Lakes, and the Gulf of Mexico as described above.
- Buoy deployments are not planned at existing ocean weather stations (i.e. HOTEL and PAPA).

BUOYS FOR SPECIALIZED MONITORING

Environmental data buoys offer an economical partial compensation for the loss of ocean station vessels for making sustained time-series observations needed to obtain a better understanding of the various dynamic processes involved in air-sea interactions. Such understanding is essential for extending the accuracy and range of environmental forecasts and for assessing the role of the ocean in producing climatic fluctuations. The use of environmental data buoys is being planned in several major experiments.

The North Pacific Experiment is a large-scale air-sea interaction study being conducted in the North Pacific. Moored and drifting buoys are being developed to obtain comprehensive information on surface meteorological and oceanographic conditions and sub-surface thermal structures to determine the influence of the ocean on seasonal weather and climate change.

The ocean as a vast reservoir of heat exerts a profound influence upon the earth's weather and climate. Due to internal forces, large oceanic thermal anomalies form which, because of their persistence produce economically significant departures from normal weather conditions. In order to achieve a capability for predicting the onset and duration of these climate variations, concurrent surface and sub-surface meteorological and oceanographic observations must be made to detect the evolution of these thermal anomalies and to monitor their complete life cycle. Environmental data buoys represent a viable platform for acquiring such data. Designing of the National Climate Program is

in progress at the time of publication of this Plan; it is too early to specify the detailed requirements for buoy systems at present.

The Mid-Ocean Dynamics Experiment is designed to establish the dynamics and statistics of meso-scale eddies, their energy sources, and their role in general ocean circulation. Moored and drifting buoys are being used in this experiment for measuring ocean currents as well as standard surface and sub-surface parameters.

The GARP Atlantic Tropical Experiment entails a comprehensive study of the structure and evolution of weather systems in the tropics to ascertain their effect on the behavior of the global atmosphere. Buoys were used during the field phase of the Experiment in mid-1974 to obtain temperature, salinity, and ocean current data as well as surface meteorological observations.

A Polar Experiment is being planned to study the effects of polar regions in the formations of major weather systems. The Arctic Ice Dynamics Joint Experiment is being conducted to relate sea-ice dynamics and ice deformation to wind and current stresses and to obtain further knowledge of the heat budget of the Arctic Ocean. The Antarctic Circumpolar Experiment is one of a series of experiments to use the southern ocean as a laboratory to monitor and study large scale dynamics and interactions between the ocean and atmosphere. In these experiments specially constructed buoys will be used as free drifters in polar waters to measure ocean currents and sea surface temperatures.

The First GARP Global Experiment is being planned to obtain a heretofore unavailable complete set of global observations in which stationary and drifting buoys will be utilized to acquire data from the global ocean. Buoy requirements for this effort are expected to be extensive and we expect other nations to participate and to coordinate the overall buoy program. At such time as the U.S. effort is decided, this Plan will be revised.

BUOY TECHNOLOGY DEVELOPMENT

A continuing research and development program will be maintained to develop required buoy systems and enhance the capability, and operational reliability and decrease the cost of environmental data buoy systems.

Emphasis will be placed on the development of drifting buoy and ice buoy systems, remote sensing of the lower atmosphere, water quality sensors and on the improvement of ocean profilers, meteorological sensors and wave measurement systems.

New hulls are to be developed for drifting buoys and for moored buoys for use in near-shore, estuarine and shallow water areas. Ways will be sought to reduce the costs of large ocean hulls. Mooring techniques and materials especially for shallow water areas will be tested. Plans also include the development of improved equipment and techniques for buoy handling and servicing.

The optimum use of satellite and navigation technology will be studied to improve the collection and relay of environmental data and the geographical positioning of drifting buoys.

Budget

The Federal Data Buoy Budget for FY 74 along with projected levels through succeeding phases are shown in the accompanying table. FY 74 represents appropriated and spending levels and FY 75 represents those items included in the present budget; the follow-on phases, corresponding roughly to fiscal years, represent estimates and are included for planning purposes only.

Federal agencies' budgeting for data buoys [Millions of dollars]

Agency	FY 74	FY 75	Phase 1	Phase 2	Phase 3	Phase 4
<u>BASIC MONITORING TO SUPPORT FORECAST, WARNING, AND ASSESSMENT</u>						
National Oceanic and Atmospheric Administration (NOAA)	3.8	3.1	2.5	6.1	6.1	4.4
Coast Guard	1.3	1.5	2.0	2.5	3.0	3.5
<u>SPECIALIZED MONITORING TO SUPPORT SCIENTIFIC RESEARCH</u>						
NOAA	1.0	1.3	1.7	1.9	2.0	2.4
Department of Defense		0.35	0.35	0.5	0.5	0.5
National Science Foundation		0.35	0.35	0.5	0.5	0.5
<u>TECHNOLOGY DEVELOPMENT</u>						
NOAA	3.7	3.2	2.8	3.0	3.2	3.2
Total	9.8	9.8	9.7	14.5	15.3	14.5

I. INTRODUCTION

Major interactions between man and the oceanic environment involve his daily decisions regarding the use of this natural resource. To make such decisions, he must monitor the state of the oceanic environment, assess the impact of his activities on that environment, and predict the ocean's future state to guide his actions. More specifically, if man is to reside nearby and work or play in the oceanic environment safely, efficiently, and enjoyably and understand it more fully, a system of marine warning, prediction, and assessment services and related research are needed. Marine observations are the foundation for these activities.

The objective of this Specialized Federal Plan for Environmental Data Buoys in the MAREP series is a planning perspective for such buoys as a component in the family of elements employed for marine environmental monitoring as the basis for environmental warnings and predictions and in support of various oceanic research projects. Although it is not feasible to publish precise fiscal information beyond the approved budget year, buoy system programming over 5 years is included in the Plan to better coordinate annual program and budget proposals by the Federal agencies involved. As environmental programs are adjusted, changes in data buoy planning will be required.

PERSPECTIVE OF THE OCEANS AND ATMOSPHERE

The upper layers of the ocean transmit all of the solar energy in and out of the sea. Because they are so intimately coupled to solar and meteorological influences, physical conditions in these layers change much more rapidly than those in the deeper ocean. Similarly, changes in the surface layers of the sea are about 25 times slower than similar transient patterns in the overlying atmosphere. Furthermore, the variability of the oceans is complicated by density differences, tides, and momentum exchanges that are unique to that environment. Because of the paucity of oceanic monitoring stations, oceanographers' knowledge of variations of the ocean with respect to time has grown very slowly.

On the other hand, physical differences from place to place were the earliest observations made by mariners. Awareness of the space variability of the oceans led to such descriptive labels as the Red Sea, the Kuro-Shio (Black Current), and the Sargasso Sea (Willow Sea). Fishermen since earliest times have used patterns of water color to locate fish and still do. The size, or scale, of the distribution of characteristics of the ocean was realized first from the CHALLENGER expedition in the year 1872. The limited mobility of sailing vessels, however, caused early scientists to emphasize features spread over 1 degree of latitude or more and forced them to assume a stationary ocean. For almost a century, oceanographic conclusions have been based on the necessary concept of an "ocean frozen in time." Obviously, only its gross anatomy could be conceived; its turbulent processes remained virtually unknown, even unsuspected.

The impetus given to oceanographic research by the requirements of the U.S. Navy during World War II resulted in the development of smaller scale sampling capabilities. Ships, improved sampling gear, and new techniques provided the capability to sample ever closer to continuity in time and space. Patterns of ocean features previously unknown were being revealed. Each extension of the sampling capability to higher frequencies has uncovered unsuspected details of small-scale anomalies in the variable conditions of the sea. From this measured capability it was found that temperature and salinity variations have scale sizes as small as 1 cm. Other components of the sea, such as the light-scattering constituents in sea water and the evaporation layer of the sea surface, approach molecular dimensions.

Movements of the ocean in the time domain have come to our attention in a similar manner. Whereas early investigators were of necessity satisfied with sampling frequencies measured in days, years, and even decades, new measuring devices and the adaptation of computer technology have permitted temporal sampling resolution to frequencies in kHz. For both the space and the time scale, new advances in the ability to sample in greater detail or at shorter intervals has resulted in new and significant insight into oceanic processes. More important, however, has been the recognition that in order to apply these newly understood processes to problems of prediction, the time and space scales must be examined simultaneously. This requirement can best be met by continuously sampling the ocean at specific locations to determine the influence of high-frequency oceanic motions on the formation of long-wavelength, large-scale anomalies. This means a continuous series of measurements at both discrete and variable locations in greater numbers than was possible from the ocean station vessels (OSV's) deployed in the Northern Hemisphere during World War II (fig.1).

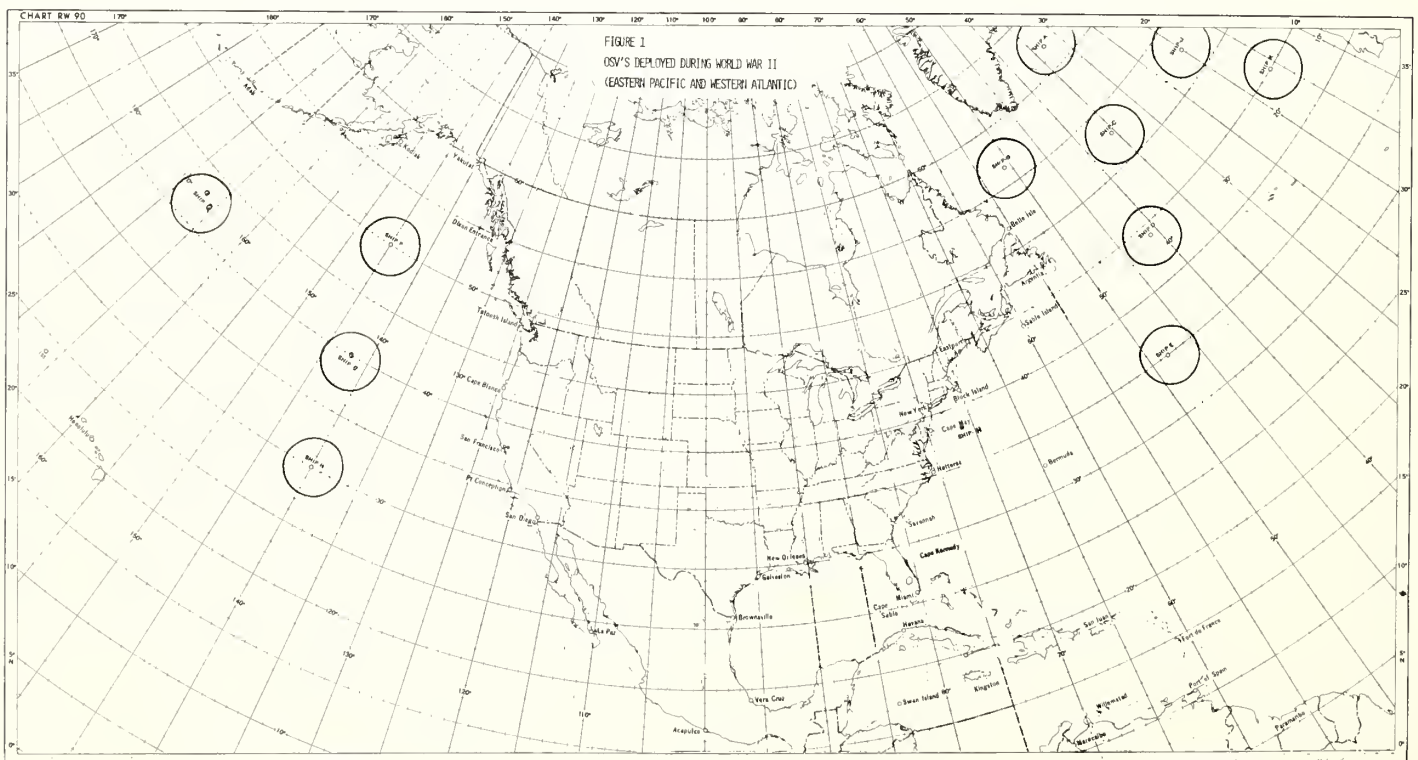


FIGURE 1

Historically, environmental observations from the oceans of the world in support of operational forecasting have been obtained from platforms that are on or over the ocean for some prime purpose other than to obtain environmental data. The primary mission of the platform determines where and when the observations are obtained. The OSV's were positioned initially on trans-oceanic flight routes as navigational aids and for search and rescue rather than for the expressed purpose of ocean-atmosphere observations.

Because of this universal practice of using platforms of opportunity to obtain operational data in support of environmental forecasting, the spatial and temporal distribution of the data has generally been less than best for meteorological and oceanographic use. Moving surface ships have been and are the main source of surface and subsurface data. Because these ships are at sea either in transit from one port to another, intent upon a minimum time or fair-weather passage, or to exploit the sea's resources, there is a concerted effort to avoid places or times when sea conditions impede progress toward the ship's destination. Thus, oceanic data are heavily biased toward daylight, fair-weather areas, coastlines, and great circle routes between principal world ports.

Efforts to overcome the lack of data from meteorologically active oceanic regions led to the use of weather reconnaissance aircraft to obtain data in the most violent storm areas in order to improve weather forecasts and to prevent excessive damage and loss of life. Aircraft equipped with newly developed remote sensors can provide marine observations, especially in coastal and Continental Shelf areas. Aircraft can fly under most clouds and can acquire extremely high resolution data. These data include observations of sea surface radiance and sea ice and indication of spills of oil and other hazardous materials. However, cost has restricted the routine use of weather reconnaissance aircraft, as have budgetary cutbacks in recent years.

Polar orbiting satellites can provide global coverage for certain marine upper air observations and descriptive mapping of sea surface radiance and ice cover in cloud-free areas. Geostationary satellites will provide near-continuous observations of areas between 55°N and 55°S and be extremely useful for storm detection and warning. An additional feature of satellites is their capability to relay data from remote platforms such as buoys, ships, and automatic weather stations to shore. The Defense Meteorological Satellite Program (DMSP), Improved TIROS Operational Satellite (ITOS), and the Geostationary Operational Environmental Satellite (GOES) satellites provide three principal types of observations: visual images, infrared images with quantitative surface radiance measurement, and (from ITOS and DMSP only) vertical atmospheric temperature profiles. Significant cloud cover now limits these observations, but may not when microwave techniques are developed and improved and other observing platforms are positioned to provide surface calibration data.

In near-shore and coastal areas, several types of facilities are available for marine observations that either measure special types of data (e.g., tides) or are available as fixed platforms of opportunity.

A major fault of most marine data, however, is the lack of fixed observing points in the oceans. Important information available from fixed stations on land and used in forecasting overland areas is the time rate of change of the various parameters measured. Only from the ocean station ships have scientists concerned with studies of the marine environment had this time-series data.

COMPENSATION FOR LOSS OF OCEAN STATION VESSELS: MOORED DATA BUOYS

Jet aircraft with their superior speed, increased range and reliability, together with new electronic navigational techniques, eliminated the need for typical ocean stations in support of transoceanic flight. Also, as personnel and maintenance costs increased, the expense of maintaining ships on station soared. As the promise of upper air information from satellites came closer to reality, reduction in the number of OSV's began. By FY 1975 there will be but one U.S.-supported ocean weather ship, and that off the Atlantic coast. The one ocean station vessel remaining in the Pacific will be OSV PAPA, operated by Canada.

The loss of the OSV's has deprived oceanographers of a major source of long-term, time-series data from the oceans. In fact, OSV's at one time were the source of some 10 percent of the routinely gathered subsurface oceanographic data available to the U.S. If compensation for OSV's is not somehow arranged, operational environmental services for activities other than aeronautics will be severely limited. Furthermore, science will lose the



OCEAN STATION VESSEL HAMILTON

continuity of an unbroken time series of ocean temperature vertical profiles that goes back more than 25 years. For scientific research and improvement of operational forecasts, the value of time series data increases in proportion to the length of the record.

Moored buoys are logical means to compensate for discontinued ocean station vessels for surface and subsurface environmental data gathering. The buoy as an unmanned platform enjoys significant cost and operational advantages over a ship's crew and can remain on station 3 years or more with minimal ship support. The buoy eliminates the high cost of the crew and provisions for their comfort and the requirement for abandoning station in the face of severe storms. Experience has shown that the buoy will continue to telemeter data even in fully developed typhoons and hurricanes.

The lower cost of data buoys compared with the OSV is reflected also by the economy of support requirements. Support can be provided by available seaworthy vessels with little modification. Existing communication facilities can be utilized to collect data from buoys after adding only supplementary automatic radio equipment. Buoys can be refurbished and overhauled at most shipyards without special provision. In this regard, data buoys can substitute for weather ships in obtaining surface, subsurface, and eventually lower atmospheric environmental data.

ENVIRONMENTAL DATA BUOY DEVELOPMENT

In the late 1950s, scientists began to realize the interactions of time-dependent and space-dependent variables in the ocean. At the same time growing technology in aerospace enabled development of a system capable of acquiring time-series data on a whole-ocean scale. A product of these two situations was the development of moored ocean data stations that could continuously measure ocean variables and transmit those data over great distances to a shore station whence the analyzed data could be reduced into useful information.

Before 1960, the use of buoys to obtain environmental data from the ocean was limited to deployment of on-board recording buoys by the Scripps Institution of Oceanography and Woods Hole Oceanographic Institution, of an elementary telemetering buoy (NOMAD) in the Gulf of Mexico by the Naval Weather Service, and of ordinary drift bottles. Except for the drift bottles, deployment of moored and drifting buoys was conducted only by the United States. These early efforts were not sophisticated, though they did represent a complete break with brute-force methods used for navigation buoys moored in shallow water. No attempt had been made to incorporate technology available from the then-burgeoning aerospace program, not even to use the newly emergent and extremely powerful digital data transfer and processing methods then at hand.

In 1960, the Office of Naval Research (ONR) began a program to develop a long-range telemetering buoy for acquiring oceanographic data from the deep sea. Drawing heavily upon aerospace technology, especially systems design, energy conversion, information systems, and quantitative field testing, this

program resulted in development of the "monster" buoy.

Advisory groups of scientists comprised a constant and significant part of the program. ONR organized a Guidance Committee, made up of leading U.S. scientists, to serve this purpose throughout the development of the buoy system.

The "monster" buoy development program incorporated state-of-the-art computer and telecommunications technology into a complete system involving oceanographic and meteorological sensors on the prototype buoys, a comprehensive interrogation station ashore, and processing and graphics facilities to present data, in near-real time, in the form of magnetic tape and analog time-series charts and X-Y station plots. This was the first comprehensive ocean data acquisition system. Performance tests at sea demonstrated the capability of telemetering digital oceanographic and meteorological data with better than 95 percent reliability, using high-frequency (HF) radio propagation, over distances greater than 3,500 miles.

By 1967, the long-time series of salinity, temperature, and depth measurements from the buoys had proved sufficiently accurate to support geostrophic computations. Also, time-series of surface meteorological data as long as 1 year, with accuracy and reliability comparable to most weather stations on land, were being obtained.

The modern telemetering environmental data buoy has presented the Nation with a significantly increased ability to measure the environment for effective



XERB-1 BUOY

monitoring, forecasting, and more incisive scientific investigation. The usefulness of telemetering buoys has been widely recognized in the past few years, leading to deployment of such buoys by several United States agencies and foreign governments.

This growing data acquisition effort and the multiplicity of agencies involved require coordination. Data from telemetering buoys will equally benefit operational environmental monitoring, forecasting, climatic assessment, and scientific research. Similarly, specially developed buoys deployed for scientific programs will also provide data to enhance operational programs. Overall control of all deployment is not necessarily desirable, but coordination of effort and routine collection and distribution of all data is essential for the most effective use of buoy technology. Coordination at the Federal level seems expedient to assure the best utilization of environmental data buoys in the national interest.

As has been noted, long-time series data are critical in recognizing changes, both manmade and natural, in the ocean and in the atmosphere above it. The best possible way to understand the long-term trends and to separate the natural changes from those induced by man is to monitor continuously the oceans and the atmosphere in key areas for a suitably long period of time.

Various workshops and symposia on use of buoy data have generally agreed on the most desired measurements from data buoys, and these are listed in table 1.

Recent investigations have summarized the need for operational and research data and have attempted to sort the parameters into priority groups. The principal conclusions are given below. In these investigations, the parameter needs of users to be satisfied by the quantity and quality of data offered by buoys measuring only a few parameters were sorted into three classes according to the present degree of need:

- Critical
- Important
- Useful

Critical parameters to be measured are:

- | | |
|--|------------------|
| (1) Air temperature | (10) Insolation |
| (2) Atmospheric pressure | (11) Wave period |
| (3) Dew point | |
| (4) Wind velocity (vector components,
or speed and direction) | |
| (5) Precipitation | |
| (6) Water pressure | |
| (7) Water temperature (surface to 300 m) | |
| (8) Wave height | |
| (9) Salinity | |

Table 1.--Desired parameters from data buoys

Parameter		Range
NOW FEASIBLE		
Air temperature -----	°C-----	-10-+40
Air pressure -----	mbar-----	900-1100
Wind speed -----	m/sec-----	0-80
Wind direction-----	degrees-----	0-360
Dewpoint-----	°C-----	-10-40
Global radiation-----	Langley/min-----	0-2
Precipitation-----	cm/h-----	0-20
Water temperature-----	°C-----	-2-35
Water pressure-----	kg/cm ² -----	0.5-55
Salinity-----	0/00-----	20-40
Sound speed-----	m/sec-----	1,410-1,580
Current Speed -----	m/sec-----	0.1-3
Current direction-----	degrees-----	0-360
Wave height (significant)-----	m-----	0-30
NOT NOW AVAILABLE		
Visibility-----	km-----	0-20
Cloud base height-----	m-----	
Cloud amount-----	percent-----	0-100
Atmospheric electricity-----	kV-----	0-10
Ambient light-----	Langley/min-----	0-0.3
Ambient noise-----	dB-----	-80- -20
Transparency-----	m-----	0-25
Wave period-----	sec-----	2-40
Wave direction-----	degrees-----	0-360
Water quality (dissolved oxygen, chlorophyll, etc.)-----		
Lower Atmosphere-----		
Temperature-----	°C-----	+1°C for each 100 mb layer to 850 mbs and preferably to 500 mbs;
Wind Vector-----	m/sec-----	+3 m/s or 10% for each 100 mb layer up to 850 mbs & preferably to 500 mbs;
Humidity-----	cm of H ₂ O-----	Water vapor profile up to 850 mbs & preferably to 500 mbs

Important parameters to be measured are: (Some, such as current velocity, were found to be critical for some data uses.)

- (12) Visibility
- (13) Bottom pressure (tidal fluctuations in depths less than 200 m)
- (14) Current velocity (vector components, or speed and direction)
- (15) Sound speed (derived from water temperature, conductivity pressure)
- (16) Wave direction

Useful parameters to be measured are:

- (17) Ambient noise (subsurface)
- (18) Biological collections
- (19) Chlorophyll
- (20) Dissolved oxygen
- (21) Ice accumulation
- (22) Transparency

Although the composite of all data needs includes many parameters measurable from buoys, most users are largely satisfied by critical and a few important parameters.

It is important to note here that data needs are continually evolving and changing and that the total requirements for many potential user agencies have not been fully established. For example, measurement of water quality and pollutant parameters may eventually be accorded higher priority.

DATA MANAGEMENT

All available meteorological synoptic reports from the buoys are placed in the standard World Meteorological Organization (WMO) formats and delivered to the National Meteorological Center for input to various computer programs and for entry into the national circuits and the international data exchange. The data are also delivered to coastal forecast offices of the National Weather Service and other users for marine warnings and for marine forecast services.

The Environmental Data Service (EDS) of NOAA is responsible for archiving meteorological and oceanographic data collected by data buoys and for providing data and data summary services to the "secondary" or "non-operational" data user communities. U.S. operators of data buoys work with EDS to establish mutually agreeable procedures and schedules for archiving these data and data summaries.

The shore processing, editing, quality control, and compression, if any, of data collected by buoys are the responsibilities of the buoy operators, and budget plans include funds necessary to prepare and copy the data for archiving. EDS provides data storage, retrieval, reproduction, summary, and display services to any requestor in the Government or private sector, domestic or foreign, on an exchange or reimbursable basis, the latter at the cost of retrieval.

EDS and the NOAA Data Buoy Office (NDBO) assist operating activities in data archiving by jointly arriving at suitable specifications for standard archival data formats, data processing requirements, and related technical criteria. Such coordination is specifically provided for in NOAA , National Science Foundation, and Navy programs.

At present, standard formats have been established to serve during implementation of data buoys under cognizance of NDBO for both fully processed oceanographic and meteorological data and data telecommunicated in WMO code forms via landlines. NDBO provides data periodically to EDS, which maintains buoy data archives at the National Oceanographic Data Center (NODC) and the National Climatic Center (NCC). With further development of capabilities for observational systems of data buoys, EDS will continue to develop and upgrade formats responsive to future requirements.

II. FEDERAL PLANNING OF BUOYS FOR BASIC MONITORING, IN SUPPORT OF FORECASTING, WARNING, AND ASSESSMENT SERVICES

To provide the oceanic data needed for long-term monitoring, forecasts, and warnings, moored operational data buoys are being developed and deployed in deep ocean areas, and eventually coastal continental shelf. An array of 36 buoys for locations in the Atlantic and Pacific is planned for completion by 1980. During this period existing buoys will be modified, and additional buoys procured with sensor systems for surface, subsurface, and lower atmospheric measurement. Table 2 shows the proposed schedule for moored operational buoys.

A prime need for environmental data from ocean areas of the world is to support analyses directed toward more accurate forecasts of the oceanic and atmospheric state and possibly toward development of oceanic and atmospheric climatic predictions. Predictions of the future state of the oceanic environment are used to support global climate analysis, commercial fisheries, recreation, ship routing, search and rescue, military operations, and improved storm warning at sea and over land. Each of these activities benefits from improved forecasts. Ability to improve forecasts, however, is seriously hindered by the lack of observational data.

Past rationale for deploying moored ocean data buoys for basic monitoring, forecast, and warning services includes support of climate research and



EB-10 EEP BUOY

Table 2.--Schedule for moored operational buoys

	<u>Phase 1</u>	<u>Phase 2</u>	<u>Phase 3</u>	<u>Phase 4</u>	<u>Phase 5</u>
Procurement:					
Buoys procured-----	0	12	12	4	-----
EEP payload replacement-----	0	4	2	-----	-----
Upper air sensors-----				20	20
Operation:					
Buoys on station-----	9	9	25	33	36
Rotating replacements-----	<u>1</u>	<u>1</u>	<u>1</u>	<u>5</u>	<u>6</u>
Total buoys operational-----	10	10	26	38	42

assessment, and overlaps with the next section of this Plan. Although a major part of the effort involved in climate assessment and prediction is research, the observation requirements are similar to those needed for forecast and warning. A National Climatological Plan for Climate Research is under preparation by Federal agencies, in which consideration is being given to deploying buoys.

The North Pacific has large changes in ocean heat content that bear on forecasts and warnings for ocean traffic, and fisheries; apparent correlation between east-west atmospheric circulation and marked deviations in equatorial waters and fisheries; and close correlation between large scale temperature anomalies in the ocean and subsequent weather over the U.S. Like the North Pacific Ocean's climatic role, the North Atlantic affects the long- and short-period changes in European weather patterns.

Certain data buoys employed to support climate research are needed in operation for relatively long periods and thus become a component of the basic oceanic monitoring effort. Two moored buoys in the North Pacific for research support will be refurbished in FY 1975 and FY 1976 and subsequently deployed with "Alpha" buoy located at 35°N and 155°W and "Dana" buoy located at 30°N and 140°W, formerly occupied by ocean station vessel "November" which has been withdrawn. At that location, Dana buoy will contribute also to the previous 25 years of time series data already available from that location.

A growing need for gathering data from the oceans on a regular basis is to support environmental quality assessment. Although pollution has become a national concern only in the recent past, there is a strong requirement growing to monitor the rate of pollution and to detect changes in the oceans that might be harmful to man or nature.

Routine observations for monitoring changes in the oceans can also be used to provide warning of events that cause damage. An array of buoys to

provide early warning can in many instances complement a viable forecast scheme.

Data obtained by environmental buoy systems would form a subset of the total national marine meteorological and oceanographic data required. Also, the data requirements best met by buoys are evolving apace with the national data requirements.

For various users, variables have different priorities, yet many users want data from essentially the same site.

For certain data uses, related groups of parameters must be measured if any of the data are to be meaningful.

In the former case, a simple example is preparing optimum ocean ship routes. Knowledge of wave height is important, as is knowledge of winds, atmospheric pressure, currents, air temperature, and tidal fluctuations. However, for predicting effects of coastal storms inland, wave conditions and currents may be of minor importance, although other parameters remain critical. Conversely, in predicting weather (which may be over land) effects in coastal waters, then waves, tidal fluctuations, and currents become critical.

Water temperature at the surface and down to about 300 meters is an example of measurements of groups of parameters. For tuna fishermen, accurate knowledge of water temperatures can help to pinpoint where tuna are most likely to be



EB-03 BUOY IN GULF OF ALASKA

found. However, other parameters are needed to detect, locate, analyze, and predict storms in the best fishing areas; otherwise fishing vessels might attempt locations on the basis of water temperature, only to find the seas and weather too rough to make the catch.

Increasing reliance on weather forecasting has led fishermen and sportsmen into coastal waters under conditions which they would have avoided in earlier days. Such reliance on available forecasts can be dangerous because of present data limitations. An example is the disaster along the Texas coast on Valentine's Day, 1969. Throughout the day, the marine forecast was for winds of 16-20 knots and seas of 4-6 ft. Consequently, the shrimping fleets from Galveston, Freeport, and Sabine left port, the smaller boats expecting to "weather" nearshore until those winds and seas abated the following morning. By 11 p.m., winds from the southeast had risen to 64 knots and seas to 22 ft. Already some of the smaller boats were in trouble, but the larger shrimpers (70-90 ft boats), relying on the limited available marine forecasts, were standing by with sea anchors out, waiting for the winds to diminish. They didn't, however; and before midnight, gale-force winds and seas higher than 25 ft had destroyed a major part of the fleet. By the morning of February 15, 32 boats were sunk (12 at sea), 7 crewmen drowned, more than 100 boats severely damaged, and the financial loss was over \$8 million.

There was no possibility of forecasting this local storm with existing techniques because it was born, grew, and died all outside the available network of observing stations. No continuously reporting stations existed in the Gulf of Mexico, though occasional data were acquired from offshore drilling platforms. Consequently, the forecast had to rely on inadequate stations along the coast. Buoys offshore could have provided significant data for making a more accurate forecast, probably saving the lives and property lost. Other examples could be related, but the need for coastal and offshore buoys to acquire data for early warning of storms is clear.

NDBO has the capability for buoy deployment to meet monitoring, warning, and forecasting data requirements. High-priority areas represented in (fig. 2) have been identified to support the following major national goals: increased safety and efficiency of exploration and transportation of energy resources in ocean areas; adequate and timely warnings of hazardous weather and sea conditions; operation of national marine monitoring to support environmental preservation; and enhancement of marine environmental information services to support offshore platform design and operations.

The depletion and shortages of oil and other fuels have caused more activity in the oceanic environment for exploration and transportation. Because of the hostility of this environment and the obligation to protect living resources, more monitoring is needed. To meet this need, buoy deployments are planned for the Gulf of Alaska and northeast Pacific to aid in continuing environmental monitoring for the marine leg of the Trans-Alaska Pipeline System (TAPS). Besides playing a major role in the environmental support of energy transportation and development in this area, buoy data will also be used for future designs of environmentally safe offshore facilities like superports, power plants, and airports.

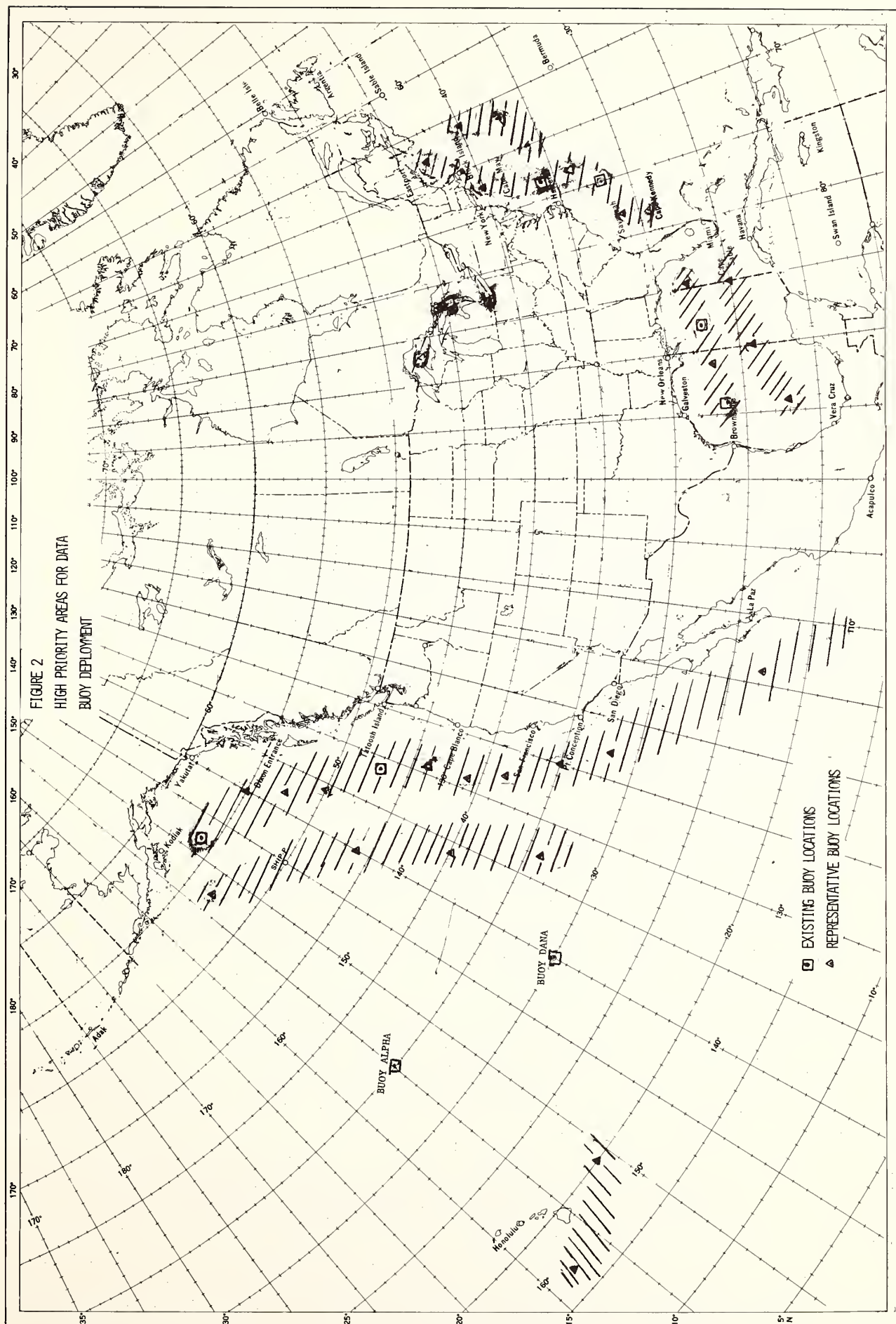


FIGURE 2

Most natural disasters that strike heavily populated areas along the Eastern Seaboard and Gulf of Mexico are ocean related. Violent hurricanes from the subtropics and winter storms that develop off the Atlantic Coast often come ashore and move rapidly inland in these heavily populated areas. Offshore marine observations are required so that adequate warning can be provided. Marine environmental observations in support of storm and hurricane warnings will be acquired through deployment of environmental data buoys along the east coast and in the Gulf of Mexico. These buoys, as those deployed for TAPS, will provide valuable information for the design, construction, and safe operation of offshore platforms.

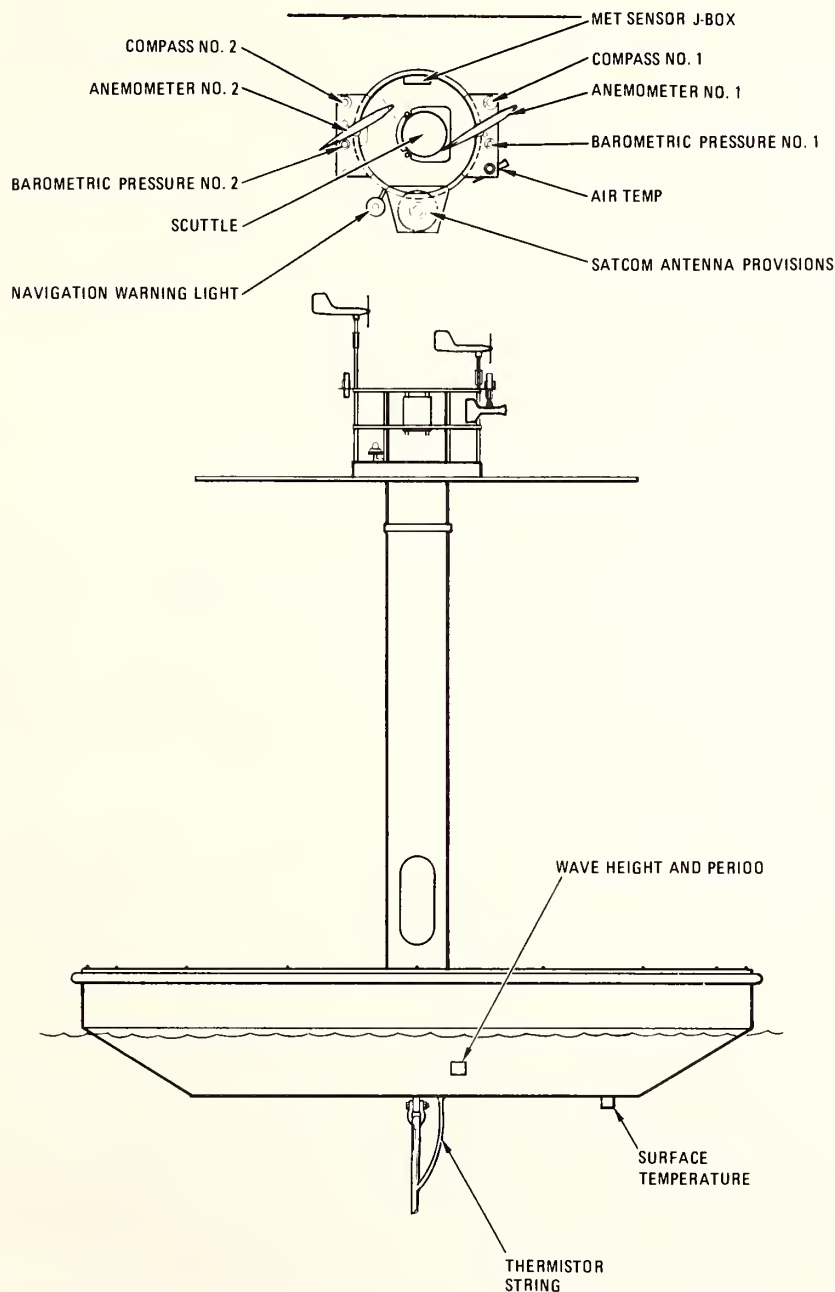
Besides support to warning and forecasts, moored data buoys in the coastal and offshore areas can monitor the physical oceanographic conditions that influence the distributions and abundances of certain living marine resources and can support deep ocean mining operations. More specifically, buoys would be used to measure changes in speed, direction, and volume transport of water (currents) and changes in the distribution and physical properties of water masses. The use of data buoys to monitor various chemical and biological conditions, although a desirable prospect for the future, is not specified here because necessary sensors are not yet developed.

Physical oceanographic (initially temperature and salinity) data are most needed for the Continental Shelf areas where most of the living marine resource species are concentrated. Specifically, data are needed to determine the axes of currents and the boundaries of water masses. Salinity, being a more diagnostic variable than temperature in waters outside the coastal zone, is the better measure of water mass differences. Equipping buoys for salinity measurements at the same depths as for temperature, or use of an oceanographic profiler, is therefore essential.

Locations and numbers of buoys. Approximately 35 buoys configured similar to that shown in Figure 3 will be required to perform these missions. This formulation is based on the following rationale:

- The primary return on investment will be in improved weather forecasting so that this should be the guiding requirement.
- Synoptic meteorological systems typically have scales of the order of 2000 km and move at speeds of the order of 30 kph. Thus, buoy spacings of the order of 500 km, 300-1000 km from shore are appropriate.
- Pacific cyclonic storms generate and move southeasterly from the Gulf of Alaska to the U.S. Pacific Coast. In the Atlantic seaboard they tend to develop and propagate to the Northeast. This requires a concentration in the Gulf of Alaska and Atlantic seaboard.
- Hurricanes in the Gulf of Mexico and typhoons near Hawaii generally move easterly and northerly. Cyclones also develop in the Gulf of Mexico.

- Existing Ocean Station Vessels Hotel and Papa provide adequate coverage in their areas. Only if a halt of their services should be planned would buoys be required in those locations.
- Areas with little ship traffic such as south of San Diego should be serviced by buoys.
- Meteorological parameters over the oceans and Great Lakes are often observed to be significantly different than our land areas. Thus a few buoys are needed in the Great Lakes



RD002D

ARRANGEMENT OF PEB

Figure 3

III. FEDERAL PLANNING OF BUOYS FOR SPECIALIZED MONITORING IN SUPPORT OF SCIENTIFIC RESEARCH

To provide needed data for the growing number of oceanic research projects, specialized buoys are being developed. Plans are to develop both drifting and moored buoy systems capable of supporting many national and international scientific programs such as GARP (Global Atmospheric Research Program) and IDOE (International Decade of Ocean Exploration). Five specialized buoy systems are now in the planning phase or under development. These include the ice buoy, small expendable drifting buoy, drifting tall buoy, expendable weather service meteorological drifting buoy, and scientific moored buoy. The ice buoy program is a continuation of the systems developed for Arctic Ice Dynamics Joint Experiment (AIDJEX). New efforts in this area are focused on providing an adequate buoy system for the Polar Experiment (POLEX) and polar requirements for GARP..

The small expendable drifting buoy program is aimed at achieving two related, but distinct capabilities:

- Lagrangian tracking of water parcels.
- Atmospheric pressure, sea surface temperature, and buoy geographic locations.

A small buoy of this type for use in "moderate environments" has just recently been developed under contract to NOVA University and is undergoing test and evaluation. Results from this testing will be used in developing a more rugged buoy for use in severe environments such as the Antarctic and southern ocean studies. In addition the small drifting buoys of this type are planned for Northern Pacific Experiment (NORPAX) and First GARP Global Experiment (FGGE).

The drifting tall buoy program is in response to needs for measuring energy flux in large-scale air-sea interaction studies such as NORPAX. As a possible alternative or complement to moored data buoys in certain areas for warnings and forecasts, an expendable meteorological drifting buoy is under evaluation for technical feasibility and economic considerations.

Three major efforts are now underway or being planned as part of the development of scientific moored buoys. These are continuation of development and deployment of two moored buoys (Alpha and Dana) by NOAA, the National Science Foundation (NSF), and the Department of Defense (DOD) as part of the NORPAX experiment; modification and use of previously developed moderate--environment buoys for use in water quality monitoring; and development of buoys for meteorological observations in coastal and Continental Shelf research programs.

Table 3 shows a development schedule for these specialized buoy systems. In addition, a brief of the scientific goals and programs that will utilize the specialized buoys is presented below.

Table 3.-Specialized Systems for Scientific Users
Development Schedule

CATEGORY	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80
ICE BUOY	Δ Develop & Test (3) Prototype Buoys Δ _____ Δ GARP A Ice Buoy Prototype Development Δ _____ Δ AIDJEX Main Experiment Δ _____ Δ Engineering Field Test Δ _____ Δ Other Experiments Δ _____ POLEX Shear Zone Experiment Δ _____ FGGE Global Coverage					
SMALL EXPENDABLE DRIFTING BUOY	Δ NOVA University Buoy Production Δ _____ Δ Scientific Experiments Δ NOVA University Buoy Prototype Development and Engineering Field Test Δ NOVA University Buoy Development Δ _____ Δ Pilot Southern Ocean Engineering/Science Experiment Δ _____ Δ Engineering Prototype Develop Δ _____ Δ Production Prototype Development Δ _____ Δ Production Δ _____ Δ Pilot Southern Ocean Experiment Δ _____ Δ Other Experiments Δ _____ FGGE Ocean Experiments Δ Buoy Design & Development Δ _____ Δ Fabricate Prototype Engineering Field Test Δ _____ Δ International Build-Up for FGGE Δ Interim SEDB Buoy Production Δ _____ Δ NORPAX Experiment Δ _____ Δ Meteorological					

Table 3. -Specialized Systems for Scientific Users
Development Schedule (Continued)

CATEGORY	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80
DRIFTING TALL BUOY	Δ Feasibility Study					
	Δ Model Development					
	Δ	Δ Engineering Field Test (3 Buoys)				
	Δ	Δ Prototype Development				
		Δ	Δ NORPAX Experiment (3 Buoys)			
		Δ	Δ Production			
			Δ			NORPAX Monitoring
EXPENDABLE WEATHER SERVICE MET DRIFTING BUOY	Δ Feasibility Study					
	Δ	Δ Engineering Prototype				
	Δ	Δ Engineering Field Test (3 Buoys)				
	Δ	Δ Production Prototype				
	Δ	Δ Engineering Field Test				
		Δ				
		Δ				
			Δ			
						Produce 20 Buoys Per Year Weather Service Operation
SCIENTIFIC MOORED BUOY	Δ	Δ ALPHA NORPAX Monitoring				
		Δ				
	LCB Shelf	Dynamics Monitoring				
	Δ	Δ	Δ	Δ	Δ	Δ
		Water Quality	Monitoring			
	Δ	Δ	Δ	Δ	Δ	Δ

For more than a century it has been known that the great surface area and high heat capacity of the earth's oceanic layer create an enormous energy reservoir which exerts considerable influence on global climate and weather. Now there is good evidence that anomalous upper oceanic thermal developments are related to changes in the atmospheric circulation and thereby modify weather conditions. But understanding of the sequence of events leading up to and including such developments and details concerning the associated exchange processes remain obscure.

The main explanations for the oceans profound influence on the earth's weather are as follows:

--The principal source of atmospheric energy is the latent, sensible and radiant heat emanating from the oceans.

--Oceanic circulation lags considerably behind atmospheric circulation because the density of water is 1,000 times that of air.

--Large oceanic thermal anomalies, once they form, tend to persist for weeks to months because the specific heat of water is about 3,300 times that of air. Thus heat is stored in the upper ocean layer to hundreds of meters in depth.

--Oceanic transport of heat from the tropics toward the pole in the Northern Hemisphere significantly exceeds earlier estimates, accounting for 74 percent of all poleward flow of heat at 30°N. This requires a major modification in numerical models of atmospheric heat energy flow and a much closer look at the day-to-day variations in the ocean than previously attempted.

In order to develop outlooks from a few weeks to many months in advance, predictions will have to be based on the lag and persistence factors involved in the ocean "heat engine." Initially, such forecasts would probably be stated in terms of departure from normal in the lower marine atmosphere and upper oceanic circulation. As insight and capabilities increased, however, it may be possible to add such details as specific areas and magnitudes of temperature anomalies, rates of growth and dissipation, and the consequent influence on weather systems that are significant to human activities.

To realize these capabilities, the following research goals are being pursued:

--Determine the evolution of large oceanic heat anomalies and their influence on the marine atmosphere.

--Develop forecasting methods that take into account these heat anomalies for more accurate long-range outlooks on oceanographic-meteorologic conditions.

--Determine the interrelationships of heat with associated events in other parts of the atmosphere and oceans.

These goals require continuous measurement of the ocean and the overlying atmosphere at enough points in the open ocean to constitute synoptic coverage. With these measurements over suitable time periods (at least longer than the time for development of major heat anomalies), the following results are expected:

- Determination of appropriate intervals (daily, 5-day, 10-day, etc.) for analyzing the various large-scale interactions to establish a more efficient monitoring network.

- Determination of the influence on the heat anomalies of extensive ocean areas that has been a dataless void (the eastern tropical Pacific, for example).

- Evaluation of the vertical distribution and changes of ocean conditions that provide the information on the storage of heat energy in the upper ocean.

- Determination of the sequence of events with respect to monthly, seasonal, and longer term developments. For this the measuring stations need not be limited to regions of the more radical and less-frequent large-scale changes, but include regions of subtle, more frequent changes. This determination will be significant in refining the normal ocean models.

- Evaluation of how reliably the sequence of development of heat anomalies and weather systems can be projected over periods longer than the measurement record.

Improving forecasts of both oceanic and atmospheric conditions imply additional needs for monitoring the oceanic environment. As the forecasting capability improves to the point of reliable estimates of the marine environment weeks or months in advance, monitoring must continue indefinitely in the same way that weather stations on land remain to support operational warning and forecast programs.

Most importantly, oceanic data must be obtained for a sufficient period of time to describe the significant natural processes and events involved in the formation and change of weather and climate, however gradual. The importance of obtaining sufficient time-series data for new oceanic experiments will be equal to that of operational monitoring to improve prediction capability. As experiments produce new understanding of the role of the oceanic environment, prediction capability should improve.

IV. FEDERAL PLANNING FOR DATA BUOY TECHNOLOGY

To increase the capability, efficiency, and reliability of data buoy systems and components, technical development, test, and evaluation will be continued. Specific planning includes the following:

- Reducing the cost of large ocean hulls and development of hulls for near-shore, estuarine, and shallow water areas.

- Development and test of mooring techniques and materials especially for shallow water areas including theoretical modeling.

- Development and improvement of sensors including no-moving-part anemometers, remote upper-air sensors, ocean profilers, wave measurement systems, and water quality detectors.

- Development of satellite communication and position fixing for buoys, using GOES and the Random Access Measurement System (RAMS) of NIMBUS F and TIROS N.

- Development and improvement of buoy power systems including air-depolarized primary and high-current secondary batteries, solar cells, and fuel cells.

- Integration and test of experimental buoy configurations including the deep-keel hull buoy and systems for Large Navigation Buoys (LNB's).

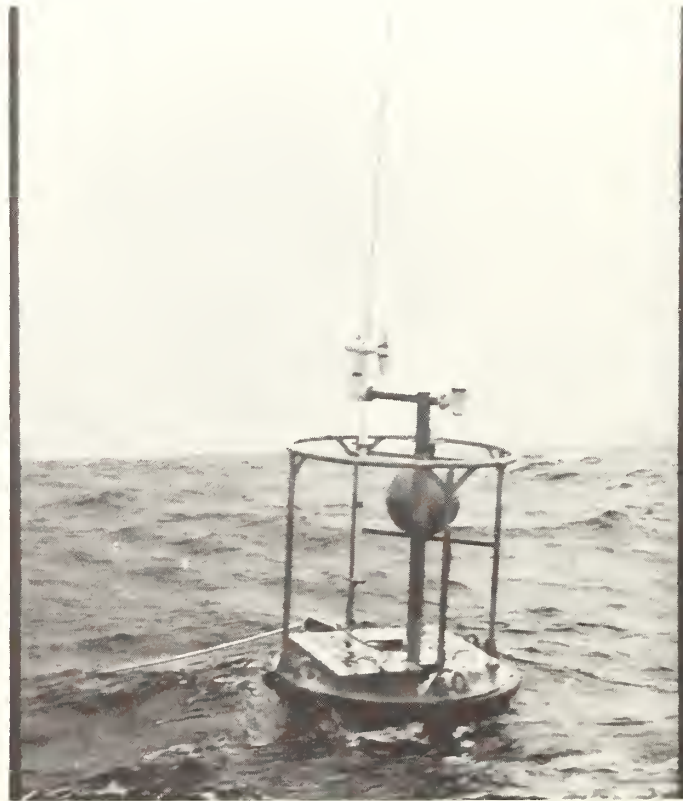
- Development of improved equipment and techniques for buoy handling and servicing.



EB-62 MODERATE ENVIRONMENT BUOY

The NOAA Data Buoy Office (NDBO), located at the National Space Technology Laboratories, Bay St. Louis, Miss. is the focus for national data buoy' technological development. NDBO conducts applied research and development necessary to develop buoy systems and to improve the capability and reliability and reduce the cost of buoy systems and components; conducts test and evaluations to assess performance and reliability of buoy systems' and serves nationally and internationally as a source of information on data buoy technology. It should be pointed out that the description of state-of-the-art buoy technology available at NDBO is partially a result of various specialized buoy development efforts, some preceding the NOAA Data Buoy project. As a center for this technology, NDBO maintains a system of information dissemination by technical reports and technology bulletins to inform other government agencies, academic institutions, and private industry of the changing state-of-the-art of buoy technology. NDBO also deploys, operates, and maintains operational buoys for users on a reimbursable basis.

The state-of-the-art in buoy hulls has advanced so that some proven shapes are now available for deployment in a variety of environments. Computer simulations are available for use in hull and mooring design, but some of these have not been verified in full scale. Model test techniques have been developed to demonstrate model performance in both regular and irregular long-crested waves and quantitatively and qualitatively in breaking waves, but without full-scale testing. Based on the data and experience above, a hull for a given use in a known environment can be designed, but the unknowns of in situ performance still dictate a conservative design, which may result in hulls that could be larger and more expensive to build and deploy than actually needed.



EB-52 DRIFTING MODERATE ENVIRONMENT BUOY

With the hull shapes that have been deployed and the analytical and model testing tools available, future efforts will focus on new and revised designs to reduce costs, providing hulls for such little-known environments as the southern oceans and for the coastal zone and gaining full-scale test data.

The state-of-the-art in deep-water mooring systems is adequate for almost any operational buoy deployment and is based principally upon well-known synthetic fiber or ferrous wire ropes, but moorings must be selected carefully. Corrosion and fishbite remain problems, but evidence indicates that synthetic lines can be sheathed to reduce fishbite damage. Corrosion and marine fouling can be controlled for a time, but antifoulant toxicity still poses an environmental problem. Future developments will concentrate on these remaining problems and on the evaluation of new materials as they become available. Work will also be done on minimum-motion mooring for measuring current at depth and on moorings for severe shallow water environments.

A combination mooring and data line, although not fully proven, appears to be a feasible method to relay oceanographic data from submerged sensors to the buoy deck unit and to supply power down to the sensors. Two general classes of mooring and data line for these purposes are under test and evaluation: inductively coupled and hardwired. Hardwiring of sensor system to the line, although a simple approach, has drawbacks: leakproof seals are required, reliability with connectors is a problem, keeping sensor data lines untangled is almost impossible, and a new line must be fabricated every time sensor depths are changed. The inductively coupled technique requires more power than hardwire, but need not be refabricated when changing sensor depths. Future work on mooring and data lines awaits results of ongoing test and evaluation programs.

In general, most basic meteorological sensors, like wind velocity, air temperature, and pressure, have demonstrated high reliability and are satisfactory for operational buoys. Future work will aim toward joint development with the meteorological community of improved sensors for long-term applications like solid state, nonmoving-part anemometers and remote sensing instruments that can make vertical temperature-humidity and eventually wind profiles of the lower atmosphere.

Oceanographic sensors now limit development of long-lived, reliable data buoy systems. Present state-of-the-art, though adequate in some parameters like water temperature, conductivity, and pressure, is unproved or inadequate in others. Especially critical are most water quality and current velocity sensors. Future work in oceanographic sensors will concentrate on the development of reliable, long-life sensors of broad application to operational programs and scientific research. Among these will be sensors for measuring surface wave characteristics and current velocity.

Development toward a profiling sensor system (one that moves up and down a line) will continue as a promising way to substantially reduce the cost of multilevel measurements in the subsurface ocean.

Power supply technology appears adequate, particularly with the reduced power demands of present components. However, requirements vary widely depending on buoy type, duration of deployment, and to some extent on ambient environmental conditions. Two general types of buoy power supplies have been successfully developed: diesel electric and battery (both primary and secondary).

The state-of-the-art in the areas of hardwired special purpose data processors and general purpose minicomputers is considered adequate for processing buoy environmental data.

Two methods for transmitting data from buoys are available. They are High Frequency (HF) communications and Ultra High Frequency (UHF) communications via satellite relay.

The HF link utilizes six bands (in 4, 6, 8, 12, 16, and 22 MHz) allocated by the World Administrative Radio Conference in 1967 for ocean data transmission. Coordination for the use of these frequencies is a joint responsibility of the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO) and must be accomplished before national administrations can register for frequency use with the International Frequency Registration Board (IFRB). Equipment for both buoys and shore collection stations required for utilizing these frequencies is readily available. Experience has indicated a high reliability of data transmittal.

Equipment is being developed for transmitting buoy data via UHF link through geostationary satellites to ground-based stations. This system is being field tested in 1974 with the first Geostationary Operational Environmental Satellite (GOES).

Drifting buoys have more complex communication problems because buoy locations must also be determined. Three different systems for determining buoy positions are under consideration: the OMEGA Very Low Frequency (VLF) Hyperbolic Ground Wave System under construction by the U.S. Navy in cooperation with other countries; the Navy Navigation Satellite System (NNSS) now in operation; and the Random Access Measurement System (RAMS), to be used in association with NASA's NIMBUS satellite program.

Test and evaluation programs by NDBO involve several geographic locations and types of buoys. Most experience has been gained from a buoy (EB-01) in the Atlantic Ocean 120 miles east of Norfolk, Va. This 40-ft discus buoy was on site from February 1970 to May 1974 except for short periods for refurbishing. Although in a test and evaluation phase, it has been operationally useful in providing data for detecting and warning of east coast winter storms. In June 1972 a second 40-ft buoy (EB-10), the first of the Engineering Evaluation Phase (EEP), was deployed in the Gulf of Mexico. EB-10, which also provides operational data, was followed by deployment of a third large buoy (EB-03) in the storm-prevalent Gulf of Alaska in September 1972.

A fourth large buoy, EB-12, in an improved configuration was deployed during June 1973 in the western Gulf of Mexico for evaluation and has performed well since that time. The more recent deployment of a large buoy has been that of EB-13 in the Atlantic Ocean east of Savannah, Ga., during December 1973.



EB-02 DEEP KEEL HULL BUOY



EB-36 MODERATE ENVIRONMENT BUOY

A Deep Keel Hull Buoy (EB-02) has been moored in the Gulf of Mexico to test this hull shape in an open ocean environment. This buoy was repositioned to the Northeast Pacific in May 1974.

During FY 1973, 10 Moderate Environment Buoys (MEBs) were partially tested and evaluated in the Gulf of Mexico. Five were moored buoys and five were designed as drifting buoys. In addition, two of the drifters were tested in an improvised shallow moor configuration. These tests were inconclusive, but indicated that MEB's would have use in the less severe environments.

MEBs measure basic meteorological parameters, i.e., wind speed and direction, air and surface water temperature, and atmospheric pressure. In addition, the moored configuration is designed to measure water temperature at prespecified depths down to 200 m.

Table 4 shows the measurement capabilities of the various data buoys of NDBO.

In the test and evaluation process, much was learned that could be incorporated into present designs to improve them dramatically-even using available hardware, since many of the problems were due to design and fabrication techniques. These problems included RF interference, grounding and voltage spike problems in digital circuitry, and fabrication for long-term exposed connectors.

NDBO is procuring its first severe-environment prototype operational buoy. This data buoy has been designed for deployment in data-sparse marine areas to meet the requirements of the National Weather Service. This system will have a low powered electronic payload featuring sensors with accuracies required for meteorological purposes; a relatively simple hardwired, low-powered data processing unit; an HF radio communications system with provisions for easy changeover to UHF; a reasonable priced, high energy-to-density ratio battery power supply with proven reliability; and a buoy platform and mooring system designed to survive the environment that can reasonably be expected in the region of deployment.

In summary, technology that still needs improvement, development, and testing includes sensors, particularly oceanographic and water quality; shallow water moorings; at-sea buoy handling and servicing; and adaptation of UHF communication equipment to buoy applications.

The U. S. Coast Guard contributes significantly to the Federal data buoy program by providing key engineering personnel to NDBO; vital at-sea and shore logistic support, particularly ships and shore facilities; and high frequency shore radio communication stations and personnel. The support has been formalized by NOAA-USCG agreement.

Table 4.-Buoy Measurement Capabilities, NOAA Data Buoy Office

	Wind direction	Wind speed	Air pressure	Air temperature	Dewpoint temperature	Precipitation	Global radiation (IR)	Global radiation (visual)	Position fixing	Wave height	Wave period	Surface water temperature	Surface Salinity	Subsurface water temperature	Current direction	Current speed
Moored severe environment buoy.	x	x	x	x	x	x	x	x		x		x	x			
Moored moderate environment buoy.	x	x	x	x								x				
Moored protected waters buoy.	x	x	x	x			x	x				x			x	x
Moored severe environment (operational) buoy.	x	x	x	x						x	x	x		x		
Drifting moderate environment buoy.	x	x	x	x					x			x				
Drifting moderate environment buoy.		x	x	x					x			x		x		
Polar ice buoy (AIDJEX)			x	x					x							
Polar ice buoy (POLEX)		x	x	x					x							

ANNEX A

Federal agencies' budgeting for data buoys [Millions of dollars]

Agency	FY 74	FY 75	Phase 1	Phase 2	Phase 3	Phase 4
BASIC MONITORING TO SUPPORT FORECAST, WARNING, AND ASSESSMENT						
National Oceanic and Atmospheric Administration (NOAA)	3.8	3.1	2.5	6.1	6.1	4.4
Coast Guard	1.3	1.5	2.0	2.5	3.0	3.5
SPECIALIZED MONITORING TO SUPPORT SCIENTIFIC RESEARCH						
NOAA	1.0	1.3	1.7	1.9	2.0	2.4
Department of Defense		0.35	0.35	0.5	0.5	0.5
National Science Foundation		0.35	0.35	0.5	0.5	0.5
TECHNOLOGY DEVELOPMENT						
NOAA	3.7	3.2	2.8	3.0	3.2	3.2
Total	9.8	9.8	9.7	14.5	15.3	14.5

ANNEX A

SUMMARY OF FEDERAL BUOY PROGRAMS

	FY 75	Phase 1	Phase 2	Phase 3	Phase 4
Federal Plan for Moored Buoys in support of basic monitoring forecast and warning services	o Procure 5 total systems	o Convert to UHF GOES communication	o Procure 12 total systems	o Procure 12 total systems	o Procure 4 total systems
	o Procure 2 payload systems for EEP hulls		o Procure 4 payload systems for EEP hulls	o Procure 2 payload systems for EEP hulls	o Procure and install upper air sensors on 21 hulls
	o Operate 6 buoys on station	o Operate 9 buoys on station	o Operate 9 buoys on station	o Operate 25 buoys on station	o Operate 33 buoys on station
Federal plan for development of specialized buoy systems	o Develop & test 3 prototype ice buoys	o Use 3 prototype ice buoys in AIDJEX		o Use ice buoys in Polex Shear Zone Experiment	o Use ice buoys in Polex Shear Zone Experiment
	o Develop GARP prototype ice buoy	o Field test GARP prototype ice buoy		o Use GARP ice buoy for FGGE	o Use GARP ice buoy for FGGE
	o Procure NOVA Medium Environment Drifting Buoy (MEDB)	o Use MEDB in experiments	o Use MEDB in experiments	o Use MEDB in FGGE	o Use MEDB in FGGE
	o Develop & test NOVA Severe Environment Drifting Buoy (SEDB)	o Use SEDB in Pilot Southern Ocean Experiment		o Use SEDB in Southern Ocean Experiment during FGGE	o Use SEDB in Southern Ocean Experiment during FGGE
	o Develop Engineering prototype (SEDB) for use in Lagrangian measurements	o Engineering Field Test of Lagrangian SEDB	o Use SEDB (Lagrangian) in Southern Ocean Experiment	o Use SEDB (Lagrangian) in FGGE	o Use SEDB (Lagrangian) in FGGE

ANNEX A

SUMMARY OF FEDERAL BUOY PROGRAMS (CONTINUED)

	FY 75	Phase 1	Phase 2	Phase 3	Phase 4
	- o Develop & procure SEDB for NORPAX - o Develop design for FGGE SEDB (MET) - o Develop & field test 3 models of Drifting Tall Buoy - o Conduct feasibility study of Weather Service Drifting Buoy - o Modify and deploy ALPHA Buoy in NORPAX - o Use limited capability buoys for Shelf Dynamics Monitoring	- o Use SEDB in NORPAX - o Fabricate prototype FGGE SEDB (MET) - o Develop prototype of Drifting Tall Buoy - o Develop & field test prototype Weather Service Drifting Buoy - o Use ALPHA & DANA Buoy in NORPAX - o Use limited capability buoys for Shelf Dynamics Monitoring - o Develop water quality monitoring system for buoys	- o Use SEDB in NORPAX - o Field test FGGE SEDB (MET) - o Procure Drifting Tall Buoy - o Procure and use 20 Weather Service Drifting Buoys - o Use ALPHA & DANA Buoy in NORPAX - o Use limited capability buoys for Shelf Dynamics Monitoring - o Develop & use water quality monitoring system for buoys	- o Use SEDB in NORPAX - o Use SEDB (MET) in FGGE - o Use Drifting Tall Buoy in NORPAX - o Procure and use 20 Weather Service Drifting Buoys - o Use ALPHA & DANA Buoy in NORPAX - o Use limited capability buoys for Shelf Dynamics Monitoring	- o Use SEDB (MET) in FGGE - o Use Drifting Tall Buoy in NORPAX - o Procure and use 20 Weather Service Drifting Buoys - o Use ALPHA & DANA Buoy in NORPAX - o Use limited capability buoys for Shelf Dynamics Monitoring

ANNEX A

SUMMARY OF FEDERAL BUOY PROGRAMS (CONTINUED)

	FY 75	Phase 1	Phase 2	Phase 3	Phase 4
Federal Plan for Buoy Technology					
		o Develop and improve buoy hulls for oceanographic and water quality measurement and for use in near shore, estuarine and shallow water areas.			
		o Develop and improve sensors: no-moving-part anemometers; lower atmosphere remote sensors; oceanographic sensors and profilers; wave meters; and water quality measurements.			
		o Develop communication capability for GOES, NIMBUS F, and TIROS-N Satellites.			
		o Develop and improve equipment and techniques for buoy handling and servicing.			

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